Center Innovation Fund: KSC CIF

Self-Cleaning Boudouard Reactor for Full Oxygen Recovery from CO2

Completed Technology Project (2015 - 2016)

Project Introduction

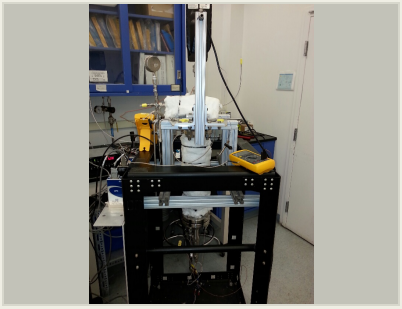
Oxygen recovery from respiratory CO_2 is an important aspect of human spaceflight. Methods exist to sequester the CO_2, but production of oxygen needs further development. The current ISS Carbon Dioxide Reduction System (CRS) uses the Sabatier reaction to produce water (and ultimately breathing air). Oxygen recovery is limited to 50% because half of the hydrogen used in the Sabatier reactor is lost as methane, which is vented overboard. The Bosch reaction is the only real alternative to the Sabatier reaction, but in the last reaction in the cycle (Boudouard) the resulting carbon buildup will eventually foul the nickel or iron catalyst, reducing reactor life and increasing consumables. To minimize this fouling, find a use for this waste product, and increase efficiency, we propose testing various self-cleaning catalyst designs in an existing MSFC Boudouard reaction test bed and to determine which one is the most reliable in conversion and lack of fouling. Challenges include mechanical reliability of the cleaning method and maintaining high conversion efficiency with lower catalyst surface area. The above chemical reactions are well understood, but planned implementations are novel (TRL 2) and haven't been investigated at any level.

Using our experience with similar chemical reactions in ISRU (in situ resource utilization), we plan to build a number of Boudouard reactors with different cleaning methods built in (such as a "wire-brush" catalyst, "spring" catalyst, or an ultrasonic water recycle loop) for testing on a Marshall Space Flight Center test stand that simulates upstream conversion of CO_2 to CO from a reverse water gas shift (RWGS) reactor for simplicity. The synthetic CO stream (which may contain H_2 to enhance the reaction) the Boudouard reactor will convert it to CO_2 and carbon fines. The gases will be analyzed with GC and mass flow meters. Peak performance as well as continuous performance after multiple regenerations will be documented to determine reactor performance. The goal is to arrive at a reactor and catalyst design which reduces or eliminates consumables with this reaction (extra catalyst or reactor swaps) which currently is 0.05 g/g oxygen recovered and would be competitive if it can be reduced by 80% or greater.

Anticipated Benefits

The current ISS oxygen recovery method utilizes the Sabatier process which is only 50% efficient due to limits on H_2 availability. This means that for a full crew over 3 kg of water/day are used in making oxygen that isn't recovered from CO_2. At current launch prices this costs up to $100,000/day, depending on the provider.

By producing a self-cleaning Boudouard reactor the single greatest challenge of the Bosch process is resolved and the full oxygen recovery of the system can be realized. The decrease in consumable requirements will be significant



One-Inch ID Self-Cleaning Boudouard Reactor and Test Stand

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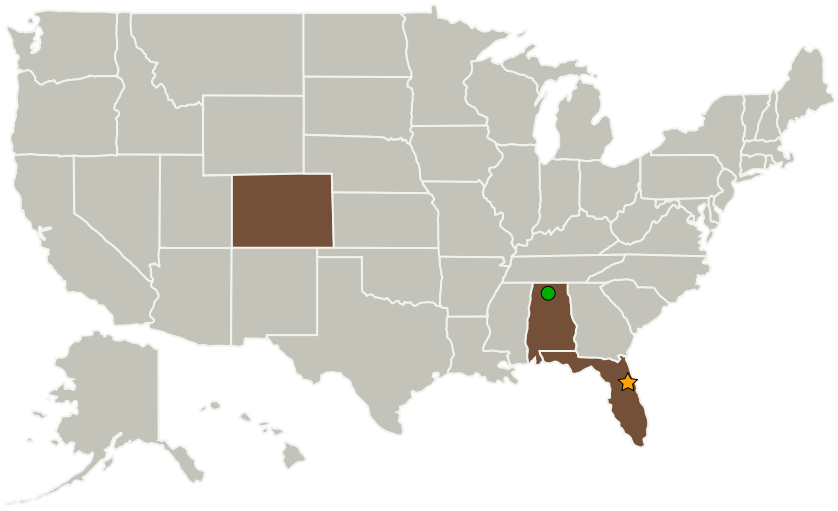
for the ISS and enabling for deep space exploration missions. In addition, **oxygen production is a limiting factor in ISS population** and a system such as this can help improve that number.

For deep space exploration missions, in-space resupply is virtually impossible so nearly 100% oxygen recovery is essential to reduce the Initial Mass in Low Earth Orbit (IMLEO). The graphite/carbon nanotube "soot" product could have applications in air or water purification filters and as a filler for 3D printing.

Crewed commercial and international spacecraft would benefit from this enhancement of full oxygen recovery from respiratory CO_2, greatly reducing consumables and resupply costs.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

Center Innovation Fund: KSC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Barbara L Brown

Project Manager:

Nancy P Zeitlin

Principal Investigator:

Anthony C Muscatello

Center Innovation Fund: KSC CIF

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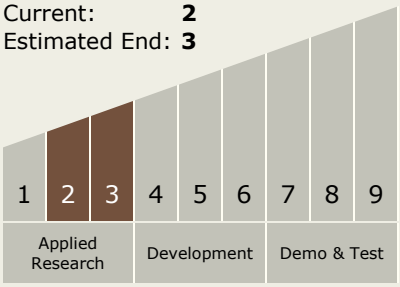
Organizations Performing Work	Role	Type	Location
★Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
●Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama
Pioneer Astronautics	Supporting Organization	Industry Historically Underutilized Business Zones (HUBZones)	Lakewood, Colorado

Primary U.S. Work Locations	
Alabama	Colorado
Florida	

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - TX07.2 Mission Infrastructure, Sustainability, and Supportability
    - TX07.2.1 Logistics Management

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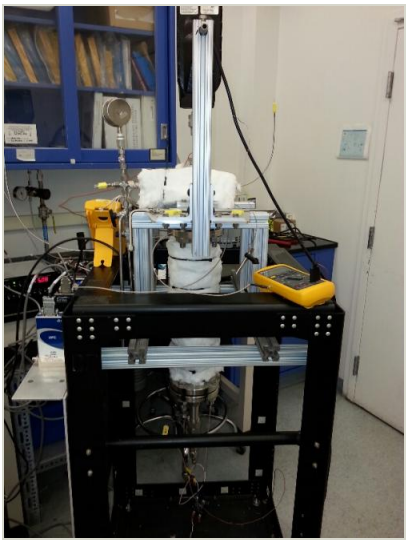
Images



One-Inch ID Self-Cleaning Boudouard Reactor and Test Stand
One-Inch ID Self-Cleaning Boudouard Reactor and Test Stand *(https://techport.nasa.gov/image/19235)*

Stories

Recent Results *(https://techport.nasa.gov/file/27915)*